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(58) Field of search
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(54) Treatment of bio-gas

(57) Bio-gas produced in the anaerobic digestion of organic waste may be cleaned and stored in a single vessel (1) which has a gas-storage space (8) and which includes a bio-gas inlet (5) and a bio-gas outlet (11). The vessel (1) is sealed by a water seal (7), the water (6) of which is continuously changing. Bio-gas is cleaned of its impurities (mainly H_2S and CO_2) by contact with the water (6) which dissolves the impurities. The bio-gas is then stored in the gas storage space (8).

Fig.1.

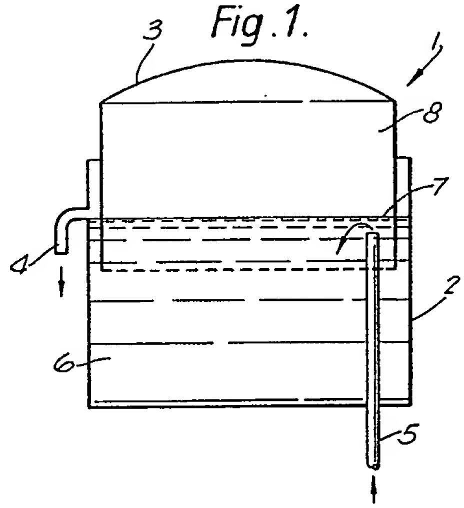

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Fig. 1.

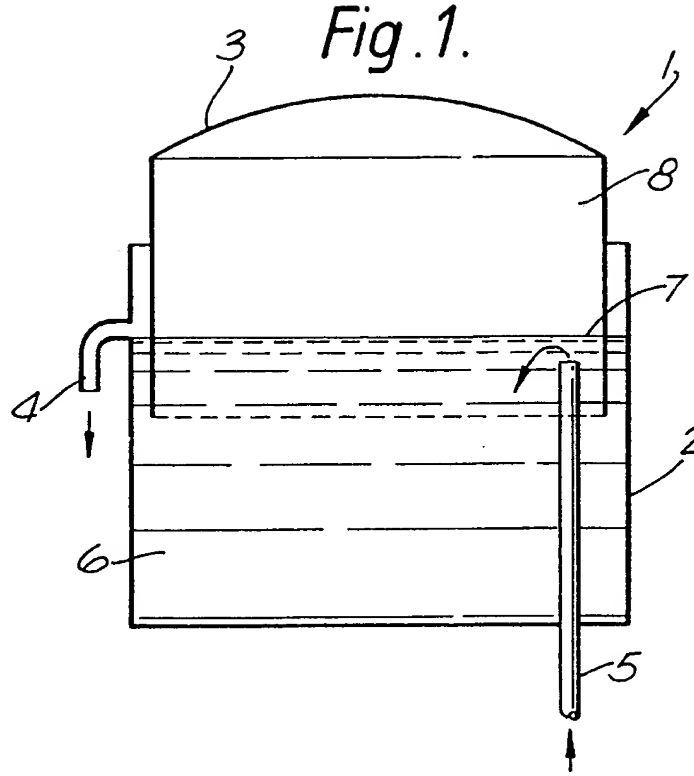


Fig. 2.

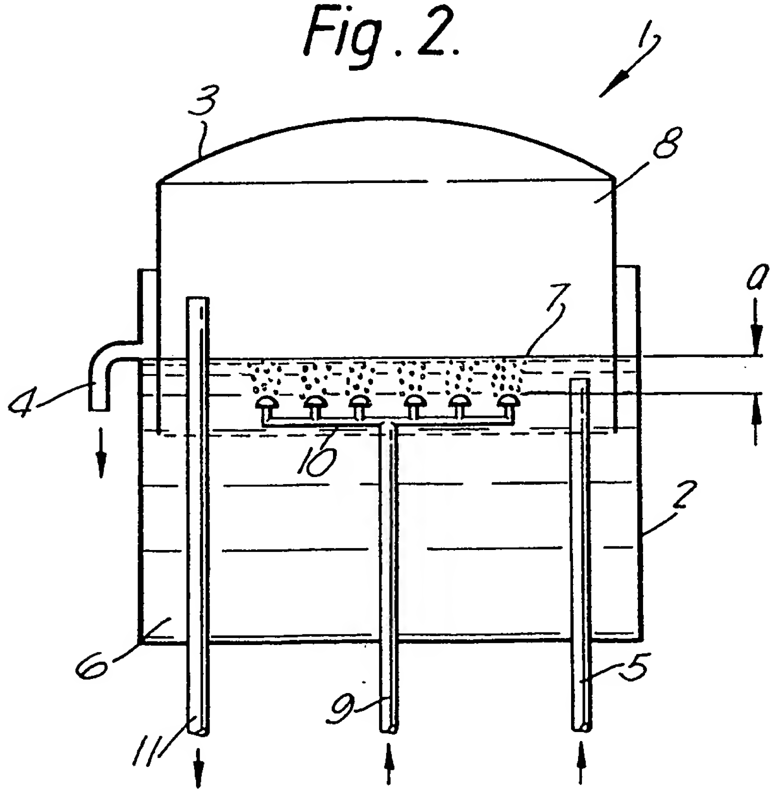


Fig. 3.

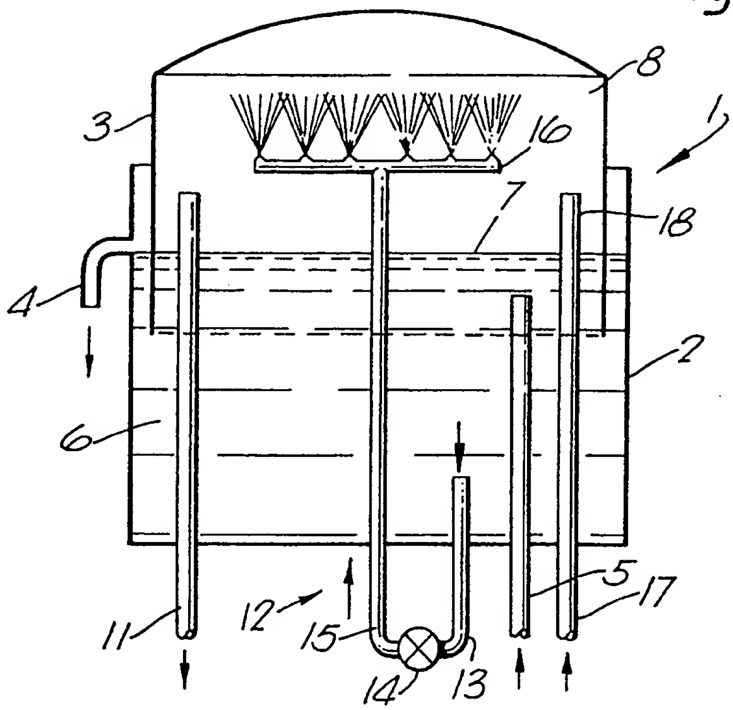


Fig. 4.

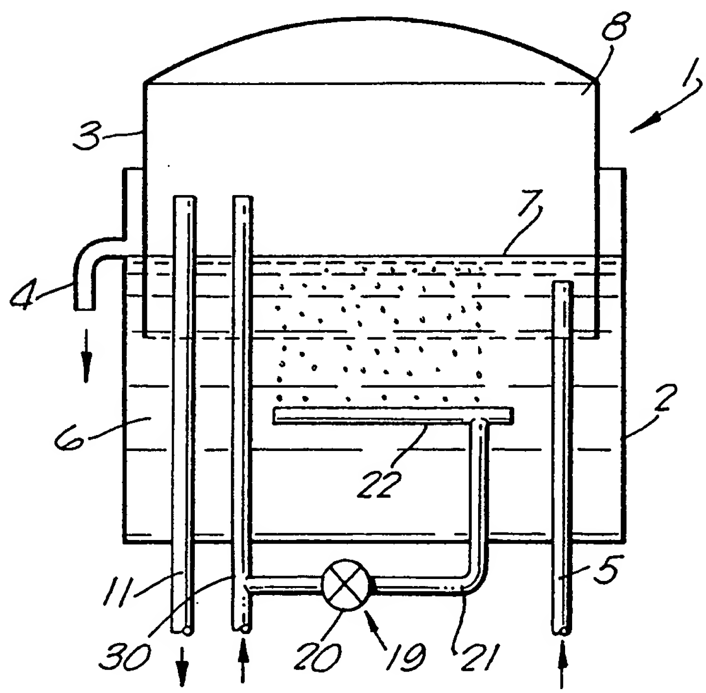


Fig. 5.

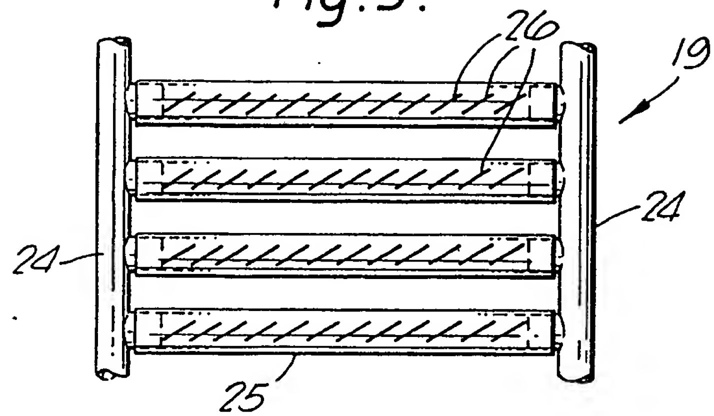


Fig. 6.

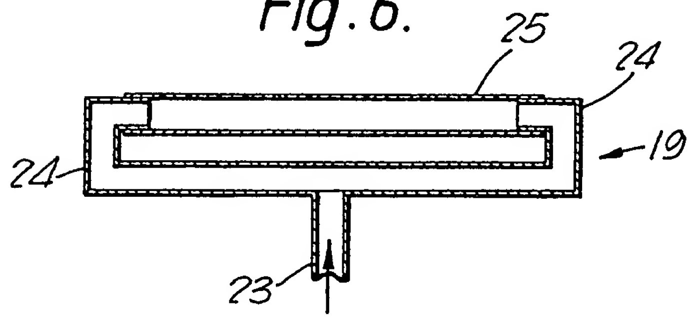


Fig. 7.

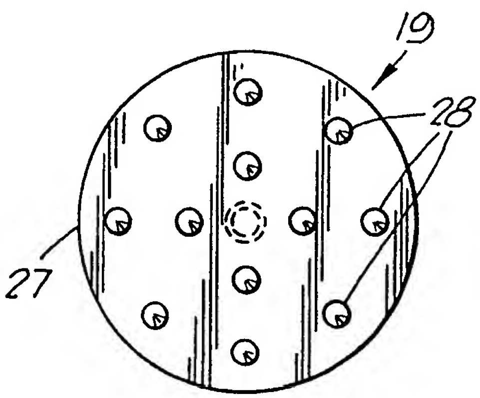


Fig. 8.

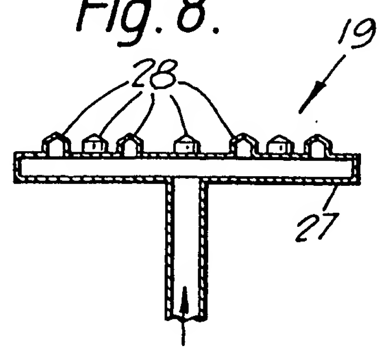
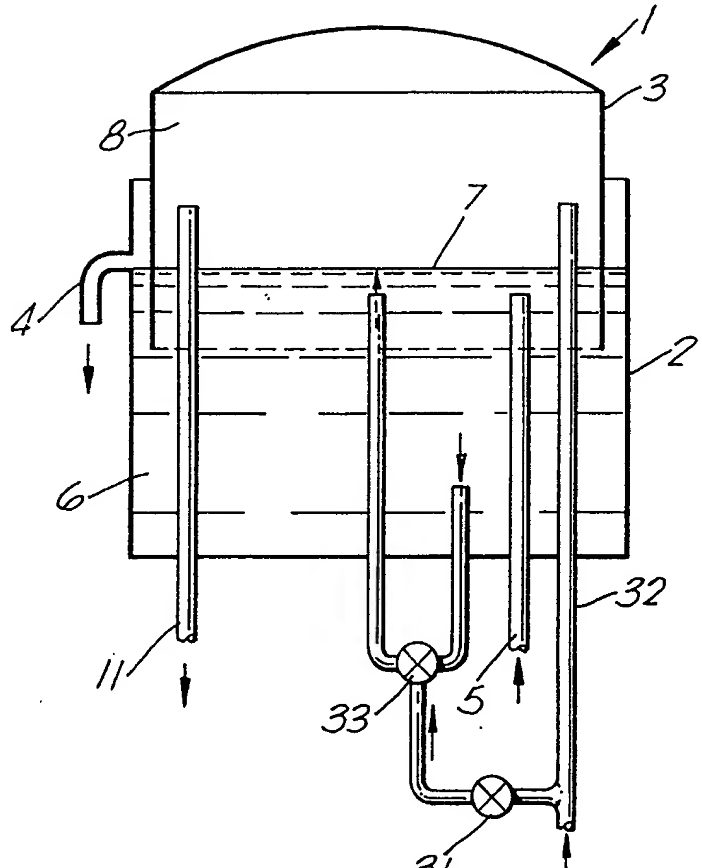


Fig. 9.



SPECIFICATION

Treatment of bio-gas

This invention relates to the treatment of bio-gas, and is more particularly, but not exclusively, concerned with a vessel for storing and cleaning bio-gas which is produced from a gas-producing organic waste digester.

Bio-gas is produced in the anaerobic digestion of sewage sludge or other organic waste and comprises mainly methane (60-70°) although it also inlcudes, in its crude state, impurities such as hydrogen sulphide (up to 0.2°) carbon dioxide (30-40°) and trace impurities which are derived from the digestion process.

Crude bio-gas may be used as a fuel for heavy duty engines such as large marine diesel engines or in heavy duty boilers. However, such engines, which are capable of being run of crude bio-gas, are very expensive to install. Although small, mass-produced, car and lorry engines and small boilers may be run off crude bio-gas, the dirty gas causes rapid corrosion of such engines or boilers, particularly at the bearings of the engines, and a dirty residue accumulates. It becomes uneconomic to run such engines or boilers off crude bio-gas because of the significant maintainance required.

At present, impurities in bio-gas may be removed by an external scrubber tower situated away from the main site of digestion. Such an arrangement, however requires additional items of plant and may substantially add to the costs involved in purification of bio-gas before the bio-gas may be used as a fuel.

According to a first aspect of the present invention there is provided an apparatus for storing and cleaning bio-gas produced by the anaerobic digestion of organic waste material, the apparatus comprising a vessel defining a gas storage space and including a bio-gas inlet and an outlet which outlet communicates with the bio-gas storage space to permit bio-gas to be removed from the storage space, wherein the gas storage space is sealed by a water seal, the water of which is continuously being renewed, and wherein the arrangement is such that said water cleans the bio-gas of at least a portion of its water-soluble impurities.

According to a second aspect of the present invention there is provided a method of storing and cleaning bio-gas comprising passing bio-gas into a bio-gas storage space which is sealed by a water seal, and permitting said water of the water seal to clean the bio-gas of at least a portion of its water-soluble impurities.

The organic waste may be any waste organic material which decomposes under anaerobic conditions to yield methane. In a sewage treatment works, the organic waste will be sewage sludge. However, organic dairy wastes, waste food, or waste materials derived in farming may all be used as the source of organic waste.

The apparatus and method of the present invention have applications not only in the water industry but also in any industry where an organic waste is subjected to anaerobic decomposition. In particular, the apparatus would enable a small farmer to economically clean bio-gas produced in the digestion of farm waste and to use the clean bio-gas to run a small generator.

The vessel should be situated downstream of and in-line with the digester producing the bio-gas and upstream of and in-line with the user of the bio-gas. All the bio-gas, therefore, should pass through the vessel before arriving at the end user. The vessel should not be used as a buffer storage space since, in such an arrangement, the bio-gas need not pass through the vessel and would not be cleaned.

The bio-gas inlet may communicate directly with the bio-gas storage space or may be arranged such that bio-gas is bubbled through the water constituting the water seal before emerging into the storage space.

As mentioned, the sealing water must be constantly changing : the spent water will be run away as waste. The sealing water may be effluent water which will be in abundance at sewage works. The sealing water may be introduced into the vessel by way of a pipe. A more elaborate technique for introducing water into the vessel may comprise spraying the water into the storage space. The sprayed water will accumulate at the water seal and eventually run away in exchange for further cleaning water. This spraying technique has the advantage that the water is brought into very intimate contact with the bio-gas and effective scrubbing can occur.

The bio-gas may be introduced directly into the storage space via a pipe. However, for more effective cleaning, the gas may be bubbled through the water of the water seal finally to emerge in a cleaned state in the storage space above the water seal. Alternatively, the bio-gas may be bubbled through the water of the water seal via a venturi device such as the VO-2 venturi device as manufactured and sold by Tom Maguire & Co. Ltd., Milford Haven. Using such a device gives rise to very vigorous mixing of the bio-gas and water and hence effective scrubbing of the bio-gas.

Depending upon the degree of purity of methane gas desired, a small quantity of a non-toxic soluble alkali, such as soda ash or potash, may be introduced into the sealing/scrubbing water supply.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 shows a basic vessel which may be used in an apparatus in accordance with the present invention;

Figures 2, 3 and *4* show preferred embodiments of apparatus in accordance with the present invention;

Figures 5 and *6* show a device suitable for introducing bio-gas into a vessel employed in the present invention;

Figures 7 and *8* show another device suitable for introducing bio-gas into a vessel employed in this invention; and

Figure 9 shows another embodiment of an apparatus in accordance with the present invention.

With reference to Figure 1, a cylindrical vessel 1 comprises a base tank portion 2 and a lid portion 3,

which lid portion 3 fits inside the tank portion 2. The base portion 2 includes an overflow pipe or weir 4 and a water inlet pipe 5.

The tank portion 2 is filled with water 6 via the water inlet pipe 5. The maximum level 7 of water 6 in the tank portion 2 is determined by the position of the overflow pipe 4. The lid portion 3, as described above, fits inside the tank portion 2 such that the water level 7 seals the lid portion 3 to provide a gas storage space 8 which is sealed with respect to the environment.

The water used for the water seal and as scrubbing water may be effluent water which is being processed in the same vicinity as the sewage sludge which is being digested. However, it is to be appreciated that the water may be derived from any reasonably clean source. In the case where the water is the effluent water supply, it will flow out of the overflow pipe 4 to the head of the works (i.e. the inlet to the sewage treatment works) where it will be subjected to the full, normal purification procedure. If the apparatus is being used by a farmer, the waste water may be put to land where the impurities will, in time, oxidise.

The exact rate of flow of water into the vessel 1 will depend on several factors, including the degree of purity of bio-gas desired, the ambient temperature of the water and the percentage of CO_2 in the crude bio-gas. However, it is believed that, as a general rule, the rate of flow of water to the rate of bio-gas production should preferably be in the range of from $0.25m^3$-$o.40m^3$ per m^3 of bio-gas produced per day.

It should be noted that the amount of CO_2 in the crude bio-gas will be quite critical in deciding the rate of flow of water since it is the CO_2 which is not highly soluble. The sulphide should be completely absorbed by the water (a) because it is present in relatively small amounts and (b) because it is relatively soluble.

In Figure 2, the basic vessel of Figure 1 is supplemented with additional features to enable it to function as a vessel for simultaneously storing and cleaning bio-gas. Thus, bio-gas is introduced into the vessel 1 via a pipe 9 and a fine bubble diffuser 10 which may be in the form of an earthenware dome. Conveniently, the fine bubble diffuser 10 will be disposed at a distance "a" below the surface 7 of the water 6 in the tank 2 and this distance "a" may be of the order of 12 inches (300mm). There is also provided a bio-gas outlet 11 via which clean bio-gas may be removed from the storage space 8.

The impure bio-gas passes through the fine bubble diffuser 10 and subsequently bubbles through the water 6 in the tank 2 as it is produced under pressure from the digester. The water 6 removes a portion of the water-insoluble impurities (particularly hydrogen sulphide gas and carbon dioxide gas) from the impure bio-gas. The cleaned bio-gas bubbles to the surface 7 of the water 6 and fills the storage space 8. The cleaned bio-gas may then be removed via the outlet pipe 11. In this arrangement, it may be necessary to increase the digester gas pressure in order to achieve bubbling of the bio-gas through the water 6 since there is now an extra head "a" of water. An increase in pressure to, for example, 18 to 24 inches water may suffice. Such an increase in pressure will necessitate replacement of the safety pressure water seal release valve on the digester to one which can accommodate the increased pressure required to overcome the head of water in the vessel.

In Figure 3, the basic vessel arrangement of Figure 1 is modified by the inclusion of a water-circulation system 12. This system 12 comprises a first pipe 13 leading from the water 6 in the tank 2 to a water-circulation pump 14, and a second pipe 15 leading from the water-circulation pump 14 to a spray-jet arrangement 16 disposed in the storage space 8. By this arrangement, water 6 from the tank is circulated and sprayed into the storage space 8 via the spray-jet arrangement 16. The water 6 cleans the bio-gas in the storage space rather than in the main body of water 6. The arrangement of Figure 3 also includes a bio-gas inlet tube 17 which terminates in an opening 18 in the storage space 8. The water sprayed will fall back into the main body of water 6 and, eventually, will leave the vessel in the normal way. The water circulation pump 14 may be controlled by a variable time clock.

In Figure 4, the basic arrangement of Figure 1 is supplemented with a diffuser arrangement 19. The diffuser arrangement 19 comprises a compressor 20 via which impure bio-gas is pressurised and then passed, via tube 21, to a course bubble diffuser 22. The course bubble diffuser 22 may be placed at a depth of 3 to 4 feet (900 to 1200 mm) below the level 7 of water 6 in the tank 2. The compressor 20 may be controlled by a periodic timer. The compressor 20 will draw bio-gas from the gas storage space 8 via pipe 30, and effectively circulates bio-gas from the storage space 8 through the water 6. This arrangement prevents the compressor from causing a potentially dangerous vacuum in the digester. Such a vacuum could draw air into the digestor through the pressure relief valve giving an explosive mixture.

Figures 5 and 6 illustrate a particular embodiment of a diffuser 19 which may be employed in the arrangement of Figure 4. Thus, Figure 6 shows in cross section a diffuser 19 including an inlet pipe 23 which branches into arms 24 to open ends of which are linked by a plastic lay flat type tube 25 having knurled slits for the escape of bio-gas. Figure 5 shows the diffuser in elevation and the knurled slits 26 can clearly be seen. The pipes 23, 24 may be made of a rigid plastic.

In Figures 7 and 8, another embodiment of a diffuser for use in the arrangement of Figure 4 is shown. This diffuser 19 is, in elevation as shown in Figure 7, a flat hollow disc 27 having slit rubber nozzles 28 which open under the gas pressure to release bio-gas into the water 6 and which close under water pressure when the compressor 20 is not operating. Figure 8 shows the diffuser in cross-section.

The apparatus of Figure 9 is based on the basic structure of the vessel of Figure 1. However, in this embodiment, a compressor 31 is provided to draw bio-gas, via the pipe 32, from the gas storage space 8. The compressor 31 pumps the bio-gas through a

venturi device 33 such as the VO-2 venturi device as manufactured by Mcguire & Co. Ltd., Milford Haven. The venturi device 33 intimately mixes the bio-gas with water 6 in the tank 2. Because the venturi device 33 gives very effective mixing of the bio-gas with the water, no diffuser arrangement is required as is the case with the apparatus of Figures 2 and 4. The venturi device and compressor may be controlled by a periodic timer.

CLAIMS

1. An apparatus for storing and cleaning bio-gas produced by the anaerobic digestion of organic waste material, the apparatus comprising a vessel defining a gas storage space and including a bio-gas inlet and a bio-gas outlet which outlet communicates with the bio-gas storage space to permit bio-gas to be removed from the storage space, wherein the gas storage space is sealed by a water seal, the water of which is continuously being renewed, and wherein the arrangement is such that said water cleans the bio-gas of at least a portion of its water-soluble impurities.

2. An apparatus according to Claim 1, wherein the bio-gas inlet line terminates beneath the water seal.

3. An apparatus according to Claim 2, wherein the bio-gas inlet line terminates in a fine bubble diffuser.

4. An apparatus according to Claim 2, wherein a compressor is provided in the bio-gas inlet line.

5. An apparatus according to Claim 4, wherein the bio-gas inlet line terminates in a diffuser.

6. An apparatus according to Claim 5, wherein the diffuser comprises a flat hollow chamber provided with slit rubber nozzles.

7. An apparatus according to Claim 5, wherein the diffuser comprises a series of rubber tubes provided with knurled slits for the escape of bio-gas.

8. An apparatus according to Claim 1, wherein the bio-gas inlet line terminates above the water seal.

9. An apparatus according to Claim 8, wherein the bio-gas inlet line terminates in a spray head.

10. An apparatus according to any preceding claim, wherein the water, which is continuously being renewed, flows out of the vessel over a weir.

11. An apparatus according to Claim 10, wherein the rate of flow of water through the apparatus to the rate of flow of bio-gas into the apparatus is in the range of 0.25 to 0.40 m^3 per m^3 of bio-gas flowing into the apparatus per day.

12. A method of storing and cleaning bio-gas comprising passing bio-gas into a bio-gas storage space which is sealed by a water seal, and permitting said water of the water seal to clean the bio-gas of at least a portion of its water-soluble impurities.

13. Bio-gas, whenever cleaned by an apparatus as claimed in any one of Claims 1 to 11 or a method as claimed in Claim 12.

14. An apparatus substantially as hereinbefore described with reference to Figure 1; Figure 2; Figure 3; Figure 4; Figures 4, 5 and 6, Figures 4, 7 and 8; and Figure 9.

Amendments to the claims have been filed, and have the following effect:-

(a) Claims 1 - 14 above have been deleted or textually amended.

(b) New or textually amended claims have been filed as follows:-

CLAIMS

1. A method of producing, scrubbing and storing bio-gas comprising the steps of:

(i) anaerobically digesting organic waste in an anaerobic digester to evolve bio-gas;

(ii) providing an apparatus comprising a vessel partially filled with water, the volume of the vessel above the water defining a bio-gas storage space which is sealed by the surface of the water, the vessel including a bio-gas outlet by which scubbed bio-gas may be removed from the storage space and a bio-gas inlet which terminates below the surface of the water;

(iii) introducing the bio-gas evolved in the digester, via the bio-gas inlet, into the vessel, the bio-gas being scrubbed of a least a portion of its water soluble impurities by the water in the vessel; and

(iv) continuously removing water from the vessel and replacing that removed water with further water such that the volume of water in the vessel remains substantially constant.

2. A method according to Claim 1, wherein the bio-gas inlet line terminates in a fine bubble diffuser.

3. A method according to Claim 1, wherein a compressor is provided in the bio-gas inlet line.

4. A method according to Claim 1, wherein the bio-gas inlet line terminates in a diffuser.

5. A method according to Claim 4, wherein the diffuser comprises a flat hollow chamber provided with slit rubber nozzles.

6. A method according to Claim 4, wherein the diffuser comprises a series of rubber tubes provided with knurled slits for the escape of bio-gas.

7. A method according to Claim 1, wherein the bio-gas inlet line terminates above the water seal.

8. A method according to Claim 7, wherein the bio-gas inlet line terminates in a spray head.

9. A method according to any preceding claim, wherein the water, which is continuously being renewed, flows out of the vessel over a weir.

10. A method according to Claim 9, wherein the rate of flow of water through the apparatus is in the range of 0.25 to 0.40 m^3 per m^3 of bio-gas flowing into the apparatus per day.

11. Bio-gas, whenever cleaned by a method as claimed in any one of the preceeding claims.

12. A sewage treatment works comprising: at least one anaerobic digester capable of digesting organic waste to evolve bio-gas and, communicating with the digester, an apparatus comprising a vessel partially filled with water, the volume of the vessel above the water defining a bio-gas storage space which is sealed by the surface of the water, the vessel including a bio-gas outlet, by which scubbed bio-gas may be removed from the storage space, and a bio-gas inlet which terminates below the surface of

the water, said vessel including means by which water may be continuously removed from the vessel and replaced by further water such that the volume of the water in the vessel remains substantially constant.

13. A method of producing, scrubbing and storing bio-gas comprising the steps of:

(i) anaerobically digesting organic waste to evolve bio-gas.

(ii) passing said bio-gas through a continuously changing volume of water to scrub the bio-gas of at least a portion of its water soluble impurities; and

(iii) collecting the scrubbed bio-gas after passage through the volume of water.

14. A method substantially as hereinbefore described with reference to Figure 1; Figure 2; Figure 3; Figure 4; Figures 4, 5 and 6, Figures 4, 7 and 8; and Figure 9.

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